August 2006

Geoexchange Heating and Cooling Systems

POUDRE SCHOOL DISTRICT

Organizational Overview

The Poudre School District serves Fort Collins, Colorado, and the surrounding communities. The district consists of 45 schools, including 5 high schools and 3 charter schools, enrolling 24,000 students. Its facilities encompass 3.7 million square feet and reflect many innovations in energy-efficiency technologies, energy management practices, and renewable energy use. The facilities are served mainly by Fort Collins Utilities, part of the Platte River Power Authority, and also by Xcel Energy at a few locations.

Summary of Best Practice

The all-electric Operations Center was built in 2002 and features a geothermal or "geoexchange" water-to-air heat pump system for heating and cooling. The center serves 38 occupants in 8,753 square feet (ft^2) of space. The geoexchange system was chosen for energy efficiency, comfort, and low life-cycle cost. To help minimize first costs and operating costs, the center was designed and built with many energy-efficient features, including extra insulation in the walls and ceilings and readily activated natural ventilation.

The geoexchange system is composed of 18 wells positioned below a paved outdoor parking lot next to the building. The closed-loop system serves nine water-to-air heat pumps (including the associated condensers, evaporators, and control valves) in the Operations Center (see **Figure 1**, page 2). Stu Reeve, the energy manager of the school district, says the operations center is "probably the most comfortable building in the district."[1] The U.S. Environmental Protection Agency's Energy Star program recognized the building as one of only two office buildings nationwide to achieve a rating in 2005 of 100. This ranking, the highest possible, means that the building is more efficient than 99 percent of other buildings of its class.

Corporate Energy Managers' Consortium Best Practice

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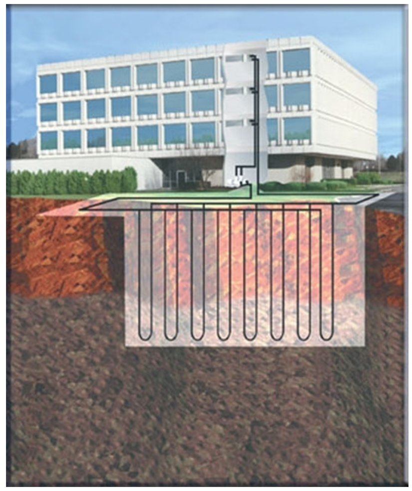
Figure 1: Diagram of external piping for geoexchange heat pump system

The vertical-loop arrangement of the underground piping allows maximum contact with the ground while reducing the surface area needed for the piping.



Courtesy: Geothermal Heat Pump Consortium Inc.

Economic Benefits

The geoexchange system has proven highly cost-effective due to its lower-than-expected initial cost and low operating costs. The estimate of the cost for the system was $442,000, but the actual installed cost was only $363,000. The engineering and contracting firms involved in the project overestimated the initial cost mainly because of their unfamiliarity with this type of system. The estimate of the cost for the alternative system of conventional rooftop units combining natural gas heating and electric cooling was $352,000, so the geoexchange system cost only $11,000 more.

The energy bill for the geoexchange facility was modeled to be $6,100 per year compared to costs for a conventional system estimated at $13,500 per year, for an estimated savings of $7,400 per year. However, the actual energy costs for the geoexchange system have been even lower: $4,200 per year for the three years ending in 2005. Thus, the geoexchange system saved about $9,300 per year compared to the conventional system, resulting in a payback period on the higher initial cost of slightly more than one year.

Other Benefits

The geoexchange system has been extremely reliable, with no significant maintenance expenses for either the well-water supply system or the space-conditioning equipment (the heat pump systems). According to Reeve, “About all we have to do is remember to change the air filters on the heat pumps.”

Even though the heat pump compressors are within cabinets located above the ceiling in occupied areas, operations are so quiet that no one notices the noise. The heat pumps easily achieve comfort levels in each of the nine zones that are served. The configuration allows heat pumps to operate in the heating mode to satisfy zones with heating needs while other heat pumps, such as those on the south side of the building, operate in the cooling mode.

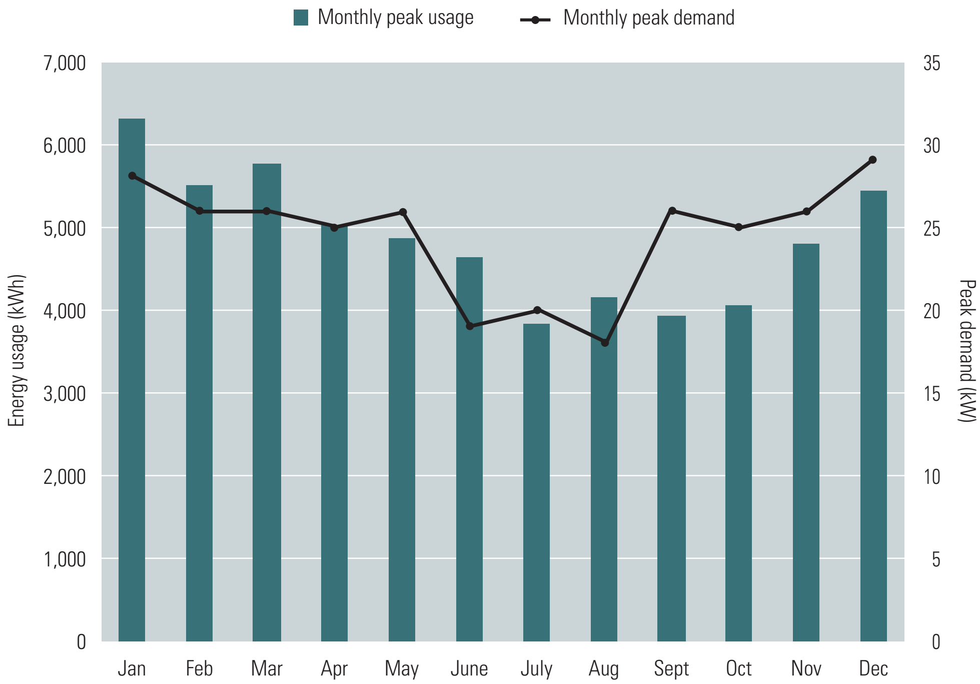
Peak demand and monthly energy use are higher in the winter months and lower in the summer months, as might be expected in the northern climate of Colorado. For example, the summer peak was about one-third lower than the winter peak for 2005, as may be seen in **Figure 2** (page 3).

Detailed Description

Geoexchange heat pumps are water-to-air systems, meaning that supply water or an antifreeze solution is circulated through a heat exchanger coil that transfers heat to or from air that is blown across the coil by a fan. In addition, geoexchange heat pumps are ground-source heat pumps, also known as geothermal heat pumps. This means that the supply fluid circulates

Figure 2: Monthly energy use and peak demand

Peak demand is about 46 percent higher in the winter months compared to the summer, and energy usage is about 37 percent higher in the winter.



Notes: kW = kilowatt; kWh = kilowatt-hour.

Source: E SOURCE; data from Poudre Valley School District

through a buried network of pipes, receiving heat from the ground during the heating season and rejecting heat into the ground during the cooling season.

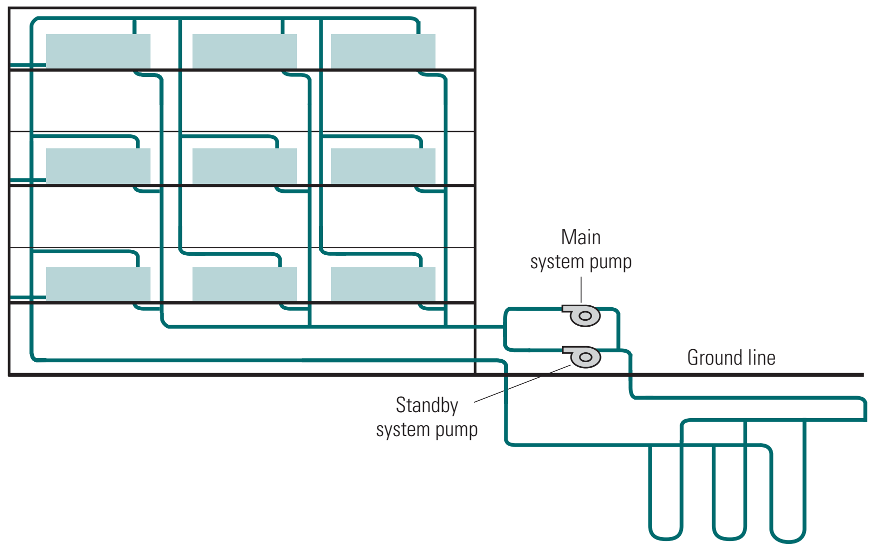
In geoexchange systems, the circulating fluid moves in a closed loop, meaning that the fluid is not supplied from or discharged to the environment. Open-loop systems are different in that they draw water from wells or from surface water, such as lakes or streams. They pass the fluid through a heat exchange unit and then discharge the water back into another well or surface waters. Open-loop systems must be designed to handle uncertainties associated with surface waters, such as debris and minerals, as well as to avoid contamination of the environment by the discharge water.

In general water-to-air heat pump systems are more efficient and provide more heating capacity at lower temperatures than air-to-air heat pumps, but they have higher initial costs. The heat pumps of the geoexchange system at the Operations Center function with a coefficient of performance of about 3, which means they provide three units of heat for each unit of electricity consumed to operate the system. The energy-efficiency rating of the heat pumps averages about 14 for the air-conditioning mode.

The Operations Center uses a closed-loop system with 18 wells, each 300 feet deep. The wells are connected in a continuous circuit with two miles of piping, as shown in **Figure 3** (page 4). The pipes are 1 inch in diameter within a 6-inch-diameter well that is then filled with grout to promote increased heat transfer. The water circulation pumps are equipped with variable frequency drives. As an alternative to the well system, horizontal ground-loop systems were considered but rejected

Figure 3: Schematic diagram of geoexchange system

The water from the underground piping is used as the heat source for nine separate heat pump systems. The cold water returned from the heat pump systems is then recirculated through the underground piping.



Courtesy: Geothermal Heat Pump Consortium Inc.

because they require much more surface area for the outdoor piping system. Open-loop water systems were excluded because of environmental concerns.

The capacity of the geoexchange system is 216 thousand Btu (kBtu) per hour (h) for heating and 120 kBtu/h (10 tons) for cooling. The temperature of the circulating water ranges between 60 and 65 degrees Fahrenheit. The temperature migrates to the lower end of the range in winter and to the higher end of the range in summer.

Inside the Operations Center, the water is circulated through a two-pipe system: a supply pipe and a return pipe. In the heating mode, refrigerant draws heat from the supply water and expands from a cool liquid to a warm, gaseous state. It is then compressed to a high-temperature gas and passed into a heat exchanger coil. Air blown across the coil absorbs the heat and is then delivered to the occupied spaces.

In the cooling mode, the operation of the refrigeration cycle is reversed so that heat is removed from the zone and transferred to the refrigerant and then to the water circulating in the return pipe. The advantage of the two-pipe system is that the water can simultaneously serve as a heat source for heat pumps in zones calling for heat and as a heat sink for heat pumps in zones calling for cooling. This helps improve the efficiency of the process.

The annual energy consumption in the all-electric Operations Center building is only 22,100 Btu/ft^2. This is well below the average of 91,900 Btu/ ft^2 per year for office buildings located in the Mountain region of the U.S.[2] About 60 to 70 percent of the building's electricity use is for the geoexchange system, with the rest being used for lighting, computers, refrigerators, and so forth.

Implementation Considerations

The district systematically encourages sustainable designs and energy-efficient operations through a "green team" of school officials engaged in planning, construction, and maintenance. The team draws on vendors for engineering, construction, and commissioning. Due in part to the cooperation among all key parties in the building development process, installation and startup of the geoexchange system went smoothly.

The team also draws on local utility personnel for advice on new technologies, applications engineering, and electric and gas service sizing and location as well as for incentives. Sharon Held, senior key accounts representative for Fort Collins Utilities, notes, "Some utilities simply announce programs for customers to figure out on their own, but we try to also provide engineering assistance and energy analysis to support customer decisions."[3]

Notes

1 Stu Reeves (June 1, 2006), Energy Manager, Poudre School District, 970-490-3502, stur@psdschools.org.

2 U.S. Energy Information Administration, “2003 Commercial Buildings Energy Consumption Survey: Consumption and Expenditure Tables” (June 2006), Table C9, p. 295.

3 Sharon Held (June 1, 2006), Senior Key Accounts Representative, Fort Collins Utilities, 970-221-6706, sheld@fcgov.com.